"Summary of "Acute Renal Failure Requiring Dialysis in the Intensive Care Unit: The Clinical and Resource Implications of Renal Recovery"

By B. Manns, C. Doig, H. Lee, S. Dean, M. Tonelli, D. Johnson and C. Donaldson

Purpose

Care of the critically ill in intensive care units is resource intense, technically involved and expensive. Some patients develop acute kidney failure that can be treated with either continuous renal replacement therapy or intermittent hemodialysis. As superiority for either modality has not been shown, it is important to examine the costs and clinical benefits of each. The purpose of this study was to determine the impact of kidney recovery on future clinical outcomes and cost of care.

Approach

Clinical outcomes and costs for patients who developed kidney failure requiring dialysis were determined in two intensive care units in Calgary between April 1, 1996 and March 31, 1999. For survivors, health services costs in the subsequent year after hospital discharge were estimated.

Key findings

The following are the key findings from the study

- 261 patients received dialysis for kidney failure in the intensive care unit and 163 patients (62.5%) died in hospital. Of the 98 patients who survived to hospital discharge, 70 recovered enough kidney function to stop dialysis;
- Overall 31% of patients were treated with intermittent hemodialysis in the two intensive care units (23.3% of the 198 kidney failure patients at one hospital and 57.6% of the 58 kidney failure patients at the second hospital);
- The cost of performing continuous renal replacement therapy ranged from $498 - $731 per day. This was three times more costly than intermittent hemodialysis ($166 per day);
- Of the 98 patients who survived to hospital discharge, 66 lived within the Calgary health region and were followed for a year after hospital discharge. Of these 66 patients. 46 recovered kidney function and 20 did not recover kidney function;
- The cost for health services was significantly higher for patients who remained on dialysis. The average direct cost of care per patient (hospital care, emergency room visits, and physician care) in the follow-up year for the 20 patients who remained on dialysis was over six times higher ($73,273) compared to the 46 patients with kidney recovery ($11,192).

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Conclusions

Studies suggest that at least 85% of intensive care unit patients with acute kidney failure will tolerate intermittent hemodialysis. If only 15% of Calgary health region patients had been treated with continuous renal replacement therapy compared to the 69% who were in fact treated then a direct cost saving of $327,000 would have been achieved over 3 years in the Calgary health region.

Variations in the choice of dialysis method exist in the two Calgary intensive care units. Immediate cost-savings could be achieved by increasing the use of intermittent hemodialysis rather than continuous renal replacement therapy for patients with kidney failure in the intensive care unit.

However, due to the high cost of ongoing dialysis after leaving the intensive care unit and poor quality of life for those patients who do not recover renal function, continuous renal replacement therapy may still be an economically efficient treatment, if it improves kidney recovery among survivors.

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Alberta Centre for Health Services Utilization Research

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Acute Renal Failure Requiring Dialysis In The Intensive Care Unit

The Clinical and Resource Implications of Renal Recovery

Technical Report

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SUMMARY

Acute renal failure can be treated with continuous renal replacement therapy or intermittent hemodialysis. There is no difference in mortality comparing the two modalities of dialysis though patients treated with continuous renal replacement therapy may have a higher rate of renal recovery. Given these considerations, an estimate of the costs of each modality may help in choosing the method of dialysis. In this study, we estimated the cost of continuous renal replacement therapy and intermittent hemodialysis in the intensive care unit and explored the impact of renal recovery on subsequent clinical outcomes and costs among survivors.

We studied a retrospective cohort of 261 critically ill patients who were admitted to two tertiary care intensive care units in Calgary between April 1, 1996 and March 31, 1999 and who developed acute renal failure requiring dialysis. The cost of performing continuous renal replacement therapy ranged from CAN $498-731 per day depending on the modality and the anticoagulant used and was at least three times as costly as intermittent hemodialysis ($166 per day). Despite similarities in baseline clinical characteristics, survivors with renal recovery had significantly less days in hospital (11.3 vs 22.5 days, $p < 0.001$) and incurred less health care costs ($11,192 vs $73,273, $p < 0.001$) over the year following hospital discharge.

We conclude that immediate cost-savings could be achieved by increasing the use of intermittent hemodialysis rather than continuous renal replacement therapy for patients with acute renal failure in the intensive care unit. Due to the high cost of ongoing dialysis, continuous renal replacement therapy may still be an economically efficient treatment if it improves renal recovery among survivors; further study in this area is required.

BACKGROUND

Care of critically ill intensive care unit patients is resource intense, technically involved and expensive. Only 3-5% of hospital beds are located within an intensive care unit, but up to 20-30% of hospital budgets are spent in the intensive care unit [1, 2]. Recent estimates suggest that 23% of patients in the intensive care unit develop acute renal failure, and a significant proportion of these require dialysis [3]. The mortality rate of patients requiring dialysis for acute renal failure in the intensive care unit (50-60%) is nearly twice as high as comparable patients without acute renal failure [4-6] and costs of care are increased by several fold [2]. Although health care providers have traditionally not questioned funding for intensive care unit care, there is a need to identify ways to improve the "efficiency" of treating intensive care unit patients, such as those with acute renal failure requiring dialysis.

Many intensive care unit patients with acute renal failure require renal replacement therapy; most centres perform continuous renal replacement therapy and/or intermittent hemodialysis. Large practice variations exist with respect to the use of continuous renal replacement therapy or intermittent hemodialysis [7, 8]. Purported advantages to continuous renal replacement therapy compared with intermittent hemodialysis include improved hemodynamic stability, the ability to remove large ultrafiltrate volumes per day enabling full nutrition, improved dialysis adequacy, and the enhanced removal of middle molecules, thought to be important in the systemic inflammatory response. However, no clinical trial has demonstrated improved survival between any of the continuous techniques and intermittent hemodialysis [5, 6, 9, 10]. In addition to survival, it is important to consider the ability of survivors to recover renal function and hence to come off dialysis ("renal recovery") when choosing a dialysis modality. Patients treated with continuous renal replacement therapy may have a higher rate of renal recovery than those treated with intermittent hemodialysis though the results of clinical studies are conflicting [5, 6, 10]. If correct, these observations are important since long-term dialysis is expensive and results in significant limitations in health-related quality of life.

Continuous renal replacement failure is more complicated than intermittent hemodialysis, requires continuous nursing supervision and differs in the costs and resources used. As such, in the absence of clear clinical evidence of superior efficacy, many programs have attempted to compare continuous renal replacement therapy and intermittent

hemodialysis on the basis of cost but these studies are inadequate because of a lack of accurate costing studies and inconsistent methodology [2, 7, 10, 11].

We conducted a retrospective cohort study of all patients admitted to two tertiary care intensive care units who developed acute renal failure requiring dialysis during a 3 year period. Our purpose was to determine a comprehensive estimate of the cost—based on sound health economic methodology—of providing different forms of continuous renal replacement therapy and intermittent hemodialysis. As a secondary purpose, we also evaluated how renal recovery influences subsequent mortality and 'downstream' healthcare costs in the subsequent year after hospital discharge.

METHODS

Subjects

The local institutional review board approved the study. The Calgary Health Region services a population of 1.3 million (0.8 million locally; 0.5 million referral base for tertiary care) and has two tertiary care hospitals that perform both continuous renal replacement therapy and intermittent hemodialysis. The Foothills Medical Centre Intensive Care unit is the regional facility for burns, trauma, and neurosurgery, as well as deals with general medical/surgical diseases. The Peter Lougheed Centre is a general medical/surgical intensive care unit. Regional cardiovascular medical-surgical patients are managed in a separate facility.

All patients admitted to these intensive care units have demographic, physiologic, and laboratory data abstracted daily and prospectively to a longitudinal administrative and research database. We identified all patients who were admitted to these two intensive care units between April 1, 1996 and March 31, 1999 with a diagnosis of acute renal failure, an elevated serum creatinine, or who received dialysis. A manual review of the patient charts using *a priori* established criteria was subsequently conducted to confirm the clinical diagnosis of acute renal failure and treatment with dialysis. Patients who received dialysis solely for the treatment of an overdose were excluded. All patients treated with continuous renal replacement therapy or intermittent hemodialysis during this time period were treated with biocompatible dialysers.

Measures

Clinical information

Information was collected on demographic factors, baseline creatinine (defined as the creatinine that was measured at hospital admission, if normal, or within six months prior to hospitalization if the admission creatinine was abnormal), the dates of first dialysis, intensive care unit and hospital discharge, and renal recovery (recorded as the day after the last required dialysis treatment), the initial dialysis modality used, and the vital status of the patient at hospital discharge. Apache II scores were assessed within the first 24 hours of admission to the intensive care unit [12]. Although its limitations in patients with acute renal failure are well known [13], the Apache II score provides information on illness severity. The Charlson Comorbidity Index [14] was calculated for patients who survived to hospital discharge. The Charlson Index measures the presence of comorbid disease and is predictive of mortality in patients with general medical illness [14] and patients with end-stage renal disease [15]. All patients were assigned a score of 2 for moderate to severe renal disease, whether or not renal recovery occurred, since the main purpose of measuring the Charlson Index was to assess the presence of non-renal comorbid diseases which may affect clinical outcomes and resource use.

Determination of vital status and renal recovery

In hospital mortality and the presence of renal recovery were abstracted from manual review of the hospital records. Mortality and renal recovery over the subsequent year post-hospital discharge was determined only for the subset of surviving patients who resided within the Calgary Health Region, for whom complete information was available. Determination of vital status after hospital discharge was done through a link with the Department of Vital Statistics, Province of Alberta. Assessment of subsequent renal recovery was done through manual review of outpatient dialysis records.

Costs

The cost of continuous renal replacement therapy

All costs are reported in Canadian $ (1 CAN$= 0.66 US$= 0.47 British£), adjusted to 1999 values using the Consumer Price Index for health care goods for Canada [16]. The cost of the continuous modalities was

assessed using micro-costing techniques where the actual supplies used were recorded.

The following elements were included in the costing analysis, with the assumptions listed beside each:

- Supplies (all disposables including the dialyser and setup): As the dialyser (Prismal M100, Hospal Industrie, Meyzien, France; CAN $175) constituted one of the largest supply expenses, the average dialyser life was determined for all patients in this study, grouped according to anticoagulation technique (heparin, regional citrate or saline flushes).

- Replacement fluid and dialysate:

  - For continuous veno-venous hemofiltration, the replacement fluid rate was 2 litres per hour; for continuous veno-venous hemodialysis, the dialysate rate was 2 litres per hour; for continuous veno-venous hemodiafiltration, the dialysate and replacement fluid rates were 1 litre per hour each.

  - Standard replacement fluid was 0.9% normal saline ($1.03 per litre), alternating every second hour with 0.45% normal saline with 75 ml of NaHCO3 ($3.30 per ampule) depending on the acid-base balance and the modality used.

  - Standard dialysate was Hemosol-lo (Ivex Pharmaceuticals Ltd, Lame UK; $15 per 5 litres), except when citrate is used as an anticoagulant in which case the dialysate is mixed locally using standard methodology [17].

- Continuous renal replacement therapy machines:

  - 4 Prisma machines (Hospal AB, Basel, Switzerland; $25,000 per machine) are required locally and provide ~940 days of service per year.

  - Conservative estimate of the fixed cost/day of service is $17.58 assuming that) an annuity factor of 7.3601 is used (Bank of Canada lending rate 6% over 10 years), and ii) machines are amortized over ten years with no resale value.

- Nursing:

  - Consistent with previous studies [11], nursing costs are excluded from this analysis since the bedside nurse providing direct patient

care performs continuous renal replacement therapy. (While extra nursing work is clearly associated with performance of continuous renal replacement therapy, local nursing managers report that they do not alter intensive care unit staffing ratios based on the number of patients treated with continuous renal replacement therapy).

- Laboratory tests:
  - Arterial blood gas and potassium: twice daily measurements using Radiometer ABL 725 (Radiometer Medical A/S, Broshoj, Denmark), as per standard local practice.
  - Since laboratory parameters are measured daily in intensive care unit patients with acute renal failure, we only considered the incremental cost of one extra sample ($24.86 per sample, which represents the cost of the machine, the supplies and technician time).
  - Monitoring of anticoagulation is dependent on the anticoagulant used:
    - Saline flushes: no monitoring of anticoagulation is required,
    - Heparin: partial thromboplastin time every 4 hours ($8 per sample), and
    - Regional citrate anticoagulation: serum ionized calcium, measured every two hours ($24.86 per sample, as measured above).
- Physician billing:
  - Claimed on a daily basis ($105) as per the Schedule of Medical Benefits, Alberta Health and Wellness

The cost of intermittent hemodialysis

We recently determined the cost of nursing, machines and supplies used for performing intermittent hemodialysis (Manns et al, in preparation). The cost of supplies for this analysis was based on hemodialysis using a high efficiency polysulfone dialyser (F8, Fresenius AG, Homburg, Germany) and bicarbonate based dialysate (500mls/min) for four hours, every second day. We assumed that 5 hours of nursing time was required ($24 per hour + 20% benefits) for every 4 hour dialysis run,

including set up and machine dispensation. Since 180 hemodialysis machines (COBE Centrysystem 3, COBE Laboratories, Lakewood, Colorado; $20,000 per machine) are required locally and provided 64,000 runs in 1999, then a conservative estimate of the fixed cost per run is $10.72, assuming that i) an annuity factor of 7.3601 is used, ii) machines are amortized over ten years with no resale value, and iii) maintenance costs for equipment are $3.08 per run. No extra laboratory tests are required for intermittent hemodialysis. Physician billing is at the same rate as for continuous renal replacement therapy, except that it is claimed only on the days that intermittent hemodialysis is performed.

Hospital costing

In-patient costing was calculated using the provincially approved methodology as set forth by the Provincial & National Management Information Systems guidelines [18, 19]. It combines allocation and assignment of all direct and indirect costs associated with an in-patient encounter from the time a patient is admitted to the hospital to the time they are discharged. The quality of the data reporting of costs in Alberta has been highly ranked by the Canadian Institutes for Health Information [20]. As such, the methodological issues that arise around collection of cost data in the USA [21], in part due to the use of prices rather than costs, and for centres in Canada which cost admissions on the basis of "case-mix grouping", do not arise with the cost data considered in this analysis. For the subset of surviving patients residing within the health region, the cost for in-hospital care, emergency room visits and day surgery was determined for the year after hospital discharge. All patients who continued on dialysis after hospital discharge were treated with in-centre hemodialysis; none were treated with peritoneal dialysis. As such, the cost of subsequent outpatient hemodialysis and high-cost drugs (erythropoietin and intravenous iron) for patients who remained on dialysis after hospital discharge was estimated as the mean cost for patients treated with in-centre hemodialysis (Manns et al, in preparation).

Physician claims

For patients who survived to hospital discharge and lived in the local health region, data on physician claims during the subsequent year was determined through a link with Alberta Health and Wellness. Aggregate data for the one-year period post-hospital discharge was collected for patients with renal recovery and for patients who continued dialysis separately.

Statistical analysis

Mean values were calculated for normally distributed variables (age, APACHE II and Charlson scores, and baseline creatinine). Length of stay variables tended to be right skewed; as such, both means and medians (with 25-75th%ile) are presented. While cost variables tended to be right skewed, 'average' means are presented to facilitate summation of total costs and budgetary impact.

Statistical comparison of age, APACHE II and Charlson scores, and baseline creatinine was done using two-sided t-tests or one-way analysis of variance for comparisons of two or more groups, respectively. Since length of stay, in-hospital and physician-related cost variables were all right-skewed, these variables were log transformed prior to statistical comparison as above. P values < 0.05 were considered statistically significant.

RESULTS

The charts of 663 patients were identified and reviewed in detail; 112 were excluded from the analysis because the patients had end-stage renal disease and were on chronic dialysis and 290 were excluded because the patient did not require dialysis, leaving 261 patients for analysis. The average age was 59.3 (57.2,61.3) (Table 1). The 6 most frequent admitting diagnoses in the study sample were septic shock in 21.0%, respiratory failure (including acute respiratory distress syndrome) not secondary to cardiogenic pulmonary edema in 13.6%, bacterial pneumonia in 10.3%, cardiogenic shock in 9.9%, post operative abdominal aortic aneurysm repair in 5.6%, and multiple trauma in 4.8%. Seventeen diagnoses were responsible for the remaining 34.2% of the study sample. APACHE II scores were similar in patients treated with continuous renal replacement therapy (27.0) and intermittent hemodialysis (27.5) as the initial modality. 163 patients (62.5%) died in hospital. Of 98 patients who survived to hospital discharge, 70 recovered enough renal function to stop dialysis.

31% of patients were treated with intermittent hemodialysis as the initial modality (23.3% of the 198 patients at the Foothills Medical Centre (mean APACHE II 29.6, 95% CI 27.2, 30.0) and 57.6% of the 58 patients at the Peter Lougheed Centre (mean APACHE II 25.2, 95% CI 24.0, 26.4)). Of patients treated with continuous renal replacement therapy, continuous veno-venous hemodialysis with heparin or saline flushes was the most commonly used modality in 1996 (60.7% of continuous renal

replacement therapy treatment days). In 1999, one year after introduction of a regional citrate anticoagulation protocol locally, continuous veno-venous hemodiafiltration with regional citrate anticoagulation was the most frequently used continuous renal replacement therapy modality, used in 44% of continuous renal replacement therapy treatment days ($p < 0.001$).

The cost of performing continuous renal replacement therapy ranged from $498-731 per day depending on the modality and the anticoagulant used and was at least three times as costly as intermittent hemodialysis ($166 per day) (Table 2). The cost of performing all of the continuous renal replacement therapy modalities was similar except for continuous veno-venous hemodiafiltration using regional citrate anticoagulation; this protocol was 39% more expensive ($731 per day) due to the need for more frequent laboratory monitoring.

Of 98 patients who survived to hospital discharge, 66 lived within the local health region. There was no statistically significant difference between these 66 patients for whom follow-up data was assessed and the 32 patients for whom no follow-up data was available in terms of age, sex, APACHE II scores, or renal recovery. Aside from differences in baseline serum creatinine, patients with (n=46) and without renal recovery (n=20) were of similar age, and had similar APACHE II and Charlson Comorbidity Scores (Table 3). Patients with and without renal recovery had similar mortality rates (15%) over the subsequent year after hospital discharge (Table 3). Despite these similarities, patients who remained on dialysis were admitted to hospital significantly more in the subsequent year than those with renal recovery (22.5 vs 11.3 days, $p < 0.001$) (Table 3). The cost for hospital care, emergency room visits, and physician claims was significantly higher for patients who remained on dialysis (Table 3). The total direct cost of care for the subsequent year for patients who remained on dialysis was substantially higher ($73,273) than for those patients with renal recovery ($11,192) ($p < 0.001$).

DISCUSSION

As expected, patients with acute renal failure requiring dialysis in the intensive care unit represented an extremely ill cohort (average in-hospital mortality rate 63%) with long hospital stays and high resource use (average in-hospital cost after the first dialysis for survivors $50,077). This cost per patient is in keeping with previous estimates [22]. Our study shows that continuous renal replacement therapy costs at

least CAN $500 per day, representing nearly 20% of the total daily cost of treating an intensive care unit patient with acute renal failure. This high cost is largely due to supplies, as no nursing expense was considered. The cost of intermittent hemodialysis was CAN $166 per day, assuming it was done every other day. The relative difference in cost for continuous renal replacement therapy and intermittent hemodialysis was similar to that noted in previous studies [2, 7, 10, 11].

Large practice variations exist (even in our two local intensive care units) with respect to the use of continuous renal replacement therapy and intermittent hemodialysis [7, 8], though the explanation of these variations is not clear from examining baseline patient characteristics. Studies suggest that at least 85% of patients will tolerate intermittent hemodialysis [5, 23]; if only 15% of local patients had been treated with continuous renal replacement therapy (compared to the 69% who were in fact treated with continuous renal replacement therapy), then a direct cost saving of $327,000 would have been achieved over 3 years locally.

The costs of continuous veno-venous hemofiltration, continuous veno-venous hemodialysis and continuous veno-venous hemodiafiltration with or without heparin anticoagulation were nearly equivalent (~$500-600 per day), compared to continuous veno-venous hemodiafiltration with regional citrate anticoagulation ($731 per day). Clearly, there are some patients for whom regional citrate anticoagulation provides measurable clinical benefit (i.e. those with heparin induced thrombocytopenia and those with frequent dialyser clotting who are at very high risk for bleeding); its use for these patients may be reasonable. For other patients who are being treated with continuous veno-venous hemodiafiltration and regional citrate anticoagulation and who are not candidates for intermittent hemodialysis, use of one of the other modalities of continuous renal replacement therapy may save resources without compromising outcomes.

The added cost of continuous renal replacement therapy does not mean that it should never be used since it may be economically efficient to use a more expensive therapy if clinical outcomes are improved or 'downstream' costs are impacted. However, at present, there is no proven difference in survival between any of the continuous techniques and intermittent hemodialysis [5, 6, 9, 10, 24, 25]. A recent meta-analysis (Tonelli et al, in preparation), which combined all the available randomized controlled trials [5, 6, 9, 10, 24, 25] found no survival benefit of continuous renal replacement therapy, despite extensive sensitivity analysis.

Considering only the above information, it would be reasonable to conclude that the majority of patients with acute renal failure in the intensive care unit should be treated with intermittent hemodialysis, in order to improve the efficiency of treatment. There may be a subset of patients, however, for whom treatment with continuous renal replacement therapy may be an efficient use of resources. This group includes those patients at highest risk for remaining dialysis dependent since previous work suggests that the proportion of patients with renal recovery may be higher among those treated with continuous renal replacement therapy compared to intermittent hemodialysis [5, 6, 10]. Our study highlights the clinical and economic importance of renal recovery among survivors. Patients in our study who recovered renal function spent significantly less time in hospital over the subsequent year. Although we did not measure health-related quality of life in this study, the poor health-related quality of life associated with chronic dialysis is well known, [26, 27] suggesting that patients with renal recovery would have better health-related quality of life. Moreover, renal recovery had a clear impact on subsequent resource use. In the year after hospital discharge, the cost of caring for patients who remained on dialysis was > $62,000 more than for patients with renal recovery.

If continuous renal replacement therapy does, in fact, improve the rate of renal recovery compared with intermittent hemodialysis, then the immediate increase in resource use related to continuous renal replacement therapy may be balanced by improved long-term clinical outcomes and downstream cost savings. Further research on the predictors of renal recovery and the effect of dialysis modality on renal recovery is clearly needed.

Our study had several limitations. Our study design did not allow us to assess the impact of dialysis modality (continuous renal replacement therapy or intermittent hemodialysis) on clinical outcomes (mortality or renal recovery). A well-powered randomized clinical trial would be required to accomplish this; we believe that our study highlights the urgent need for such a trial. We were only able to ascertain accurate follow-up information on 66 of the 98 patients who survived to hospital discharge. The other 32 patients were referred in to our local health region for treatment of their critical illness. Since their follow-up care occurred predominantly outside of Calgary, we could not accurately assess subsequent hospital use. Finally, we did not measure health-related quality of life in survivors with and without renal function; it seems reasonable to expect that health-related quality of life would have been reduced more significantly in patients requiring chronic dialysis.

CONCLUSIONS

Immediate cost-savings could be achieved by increasing the use of intermittent hemodialysis rather than continuous renal replacement therapy for patients with acute renal failure in the intensive care unit. For patients who are at high risk of remaining dialysis dependent, continuous renal replacement therapy may still be an economically efficient treatment, if it improves renal recovery among survivors. A well-designed clinical trial investigating the effect of dialysis modality on renal recovery is needed to guide clinical decision making in the intensive care unit.

Table 1: Baseline Characteristics and the Effect of Renal Recovery and Vital Status at Hospital Discharge On Length of Stay and In-Hospital Costs

Status at hospital discharge	Alive with renal recovery (n=70)	Alive on dialysis (n=28)	Dead (n=163)
Age (sd)	58.2 (17.1)	56.1 (16.8)	60.3 (16.5)
Initial Apache II score (sd)	22.5 (7.5)	20.4 (5.4)	28.7 (8.6)§
Baseline creatinine in umol/l, n=181* (sd)	142 (63)	198 (145)	143 (89) †
Mean (median, 25-75th%ile) number of days in the ICU after first dialysis	10.3 (7, 3-15)	11.1 (5, 2-17)	8.9 (5, 2-13)
Mean (median, 25-75th%ile) number of days in the hospital after first dialysis	38.2 (32, 16-53)	47.7 (33, 17.5-62)	12.2 ¶ (5, 2-16)
Mean in-hospital costs after first dialysis	$47,694	$56,035	$29,425 ¶

* Baseline renal function was unknown in 80 patients

§ $p<0.001$ for comparison of 3 groups using one-way analysis of variance

† $p=0.03$ for comparison of 3 groups using one-way analysis of variance

¶ $p<0.001$ for comparison of 3 groups using log-transformed variables (since distribution right-skewed) and one-way analysis of variance

Table 2: Baseline Daily Cost of Continuous Modalities and Intermittent Hemodialysis for Acute Renal Failure in the Intensive Care Unit

Cost per day	CVVH	CVVHD	CVVHDF	Intermittent hemodialysis (done every second day)
Supplies (incl. dialyser) *				$56.92 per run
No anticoagulation	$288.22	$306.67	$306.67	
Heparin anticoagulation	$173.78	$183.13	$183.13	
Citrate anticoagulation	N/A	N/A	$248.21	
Replacement fluid §	$128.64	0	$64.32	0
Dialysate ¶				$10.10 per run
Non-citrate	0	$147.36	$73.68	
Citrate (excluding pharmacist time)	N/A	N/A	$22.42	
Machines	$17.58	$17.58	$17.58	$10.72 per run
Nursing	0	0	0	$149.62 per run
Lab tests				N/A
No anticoagulation ¥	$24.86	$24.86	$24.86	
Heparin anticoagulation †	$72.86	$72.86	$72.86	
Citrate anticoagulation ‡	N/A	N/A	$273.46	
Physician billing	$105	$105	$105	$105 per run
Total cost per day				$332 per run / $166 per day
No anticoagulation	$564	$601	$592	
Heparin anticoagulation	$498	$526	$527	
Citrate anticoagulation	N/A	N/A	$731	

* Adjusted for the average number of dialysers used per day (1.23, 0.62 and 0.59 per day on average for no anticoagulation, heparin anticoagulation and regional citrate anticoagulation)
§ Assumes replacement fluid rate of two litres per hour for continuous veno-venous hemofiltration, and one litre per hour for continuous veno-venous hemodiafiltration
¶ Assumes dialysate rate of two litres per hour for continuous veno-venous hemodialysis, and one litre per hour for continuous veno-venous hemodiafiltration
¥ Assumes one additional arterial blood gas and potassium sample sent per day (as per usual practice)
† Assumes partial thromboplastin time done every 4 hours to monitor anticoagulation status (as per usual practice)
‡ Assumes serum ionized calcium monitored every two hours to monitor anticoagulation status (as per usual practice)

Table 3: The Effect of Renal Recovery on Clinical Outcomes and Costs In Hospital Survivors for the One-Year Period Following Hospital Discharge

	Patients with in-hospital renal recovery (n=46) *	Patients who were on dialysis at hospital discharge (n=20) *
Age (sd)	59.4 (19.0)	54.9 (18.8)
Initial Apache II score (sd)	22.9 (5.6)	20.2 (4.7)
Charlson comorbidity index (sd)	4.6 (1.9)	4.4 (1.8)
Baseline creatinine in umol/l, n=58 † (sd)	145 (6)	221 (149) ¶
Renal recovery in subsequent year	N/A	2 (10%)
Death in subsequent year	7 (15.2%)	3 (15%)
Mean (median, 25-75th%ile) hospital days in subsequent year	11.3 (0, 0-11)	22.5 (16, 0-32) ‡
Mean hospital costs in subsequent year	$8,199	$17,596 ‡
Mean physician billing in subsequent year	$2,710	$8,791 ‡
Mean cost of outpatient hemodialysis in subsequent year	0	$36,013
Mean cost of day surgery / emergency room visits in subsequent year	$283	$961 ‡
Mean cost of high-cost drugs (Erythropoietin, intravenous iron) in subsequent year	0	$9,912
Overall direct cost of health care in subsequent year	$11,192	$73,273 ‡

* Note: this analysis includes only the 66 (of 98) survivors who were resident within the local health region for whom data collection was complete
† Baseline renal function was unknown in 8 patients
¶ p=0.009 for comparison of patients with and without renal recovery
‡ p<0.001 for comparison of patients with and without renal recovery after log transformation of all variables (since distribution right-skewed)

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